Weird notions that drive science

Strange Matters: Undiscovered Ideas at the Frontiers of Space and Time
by Tom Siegfried
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For almost 30 years, physicists have been facing a long haul across the almost interminable desert to the grand unified theory (GUT) of strong, weak and electromagnetic forces. This theory postulates an almost unimaginably huge gap between the energies of current particle accelerators and those at which the manifestations of unification become most apparent. If that's not sufficiently daunting, string theorists have speculated further, suggesting that gravity is tied to the other three interactions at an even higher energy scale.

However, in the past few years some theorists have begun to question whether this desert is real. String theory has long postulated the existence of additional spatial dimensions, beyond the three that we know, but these have always been thought to be microscopic. It has recently been suggested that some of these dimensions may be as large as a millimetre. To see how a dimension can have size, imagine tightly rolling a sheet of paper; the resulting 'curled' dimension will be much smaller than the original dimension. If these dimensions are a millimetre in size, the extraordinary and mysterious weakness of gravity relative to the other three forces could be due to its leakage into other dimensions. If that's right, unification could be just around the corner. Instead of trekking across a vast featureless energy expanse, we may well see radical departures from physics as we know it in laboratory experiments any day now. These will tell us whether or not the large extra dimensions are just a theoretical mirage.

Both the GUT desert and these large extra dimensions are motivated, at least in part, by elegant mathematics. This 'prediscovery' of physical phenomena — their discovery in mathematical equations that anticipates their discovery in the laboratory — is the unifying thread of Tom Siegfried's enjoyable new book, *Strange Matters*. Although the eponymous matter here is most literally strange-quark matter, which is discussed in the opening chapter, other ideas, such as mirror matter, large extra dimensions, supersymmetry, dark matter, unification, string theory and even extra time dimensions are, by any reasonable standard, also pretty strange.

These subjects, as well as a variety of interspersed curious historical vignettes (could Edgar Allan Poe really have inspired the physicist Alexander Friedmann to ponder an expanding Universe?), all serve to illustrate the intriguing power of mathematics in describing the physical Universe. The end result is not just a tour of current theoretical speculation on time, space and matter, but rather a cogent argument as to why we should take these exotic ideas seriously.

The consistent success of mathematical equations in describing physical phenomena has surprised and enticed scientists and philosophers for years. Siegfried's point is that mathematical physics is not just numerology or catalogues. There is something deeper, as can be seen in the numerous cases where scientists have been able to get more out of the equations than they put in. Paul Dirac's equations to describe the relativistic quantum behaviour of electrons required the existence of positrons — positively charged particles subsequently discovered by Carl Anderson. Friedmann's 'prediscovery' of the Universe's expansion presaged its observational discovery by Edwin Hubble. Wolfgang Pauli's neutrino, which was first required to satisfy energy conservation, was then found in particle beams.

Today an assortment of curious phenomena arise in the mathematics of theoretical physics. Which, if any, of these will be confirmed in the laboratory? Will it be superstrings? Strange-quark matter? Large extra dimensions? Elementary-particle dark matter? Siegfried explains each of these questions, usually with clarity and integrity. Physicists will be gratified by his testimonial in support of the Big Bang, and impressed that he managed to work in an accurate description, accessible to the layman, of the branch of mathematics known as group theory.

The choice of topics is rather unusual, beginning with a search for strange-quark matter (something a bit off the beaten path of physics today) and then moving on to supersymmetry, string theory and large extra dimensions, which are central currents of modern particle theory. But this eclectic mix helps to set the book apart from other recent popular books on similar subjects. Although the prose is at times a bit dry, the pace is just right and the presentation engaging. Except for a few notable cases (such as a proposal that extrasolar planets are made of mirror matter), the discrepancy between the well established, plausible, unlikely and far-fetched is discerned clearly.

There is also some subtle humour. For example, at the end of the book Siegfried discusses duality — roughly speaking, this is the notion that several theories that seem

High noon at the meridian

Among the 5,000 scientific instruments at the National Maritime Museum at Greenwich in London, UK, is a remarkable collection of sundials and related instruments, ranging in origin from the Far East and Islamic countries to London itself. It includes dipleidoscopes, like the one shown here, which were used to provide an accurate time check at noon, when the Sun passed over the meridian of the observer. The collection is catalogued in extraordinary detail in *Sundials at Greenwich: A Catalogue of the Sundials, Horary Quadrants and Nocturnals in the National Maritime Museum, Greenwich* (Oxford University Press, £99.50), edited by Hester Higton. The book also includes chapters that set the instruments in a cultural and historical context.

to describe different physical situations can actually be mathematical equivalents. This concept comes in handy when he tries to reconcile the apparent inconsistency in the thesis of this book — that great ideas drive progress in science — to that in his previous book, *The Bit and the Pendulum* (John Wiley, 2000), which postulates that technological advances drive scientific discovery. Although duality is not meant to imply that you can always have it both ways, in this case maybe he can. ■

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A social activist in genetics

Making Genes, Making Waves: A Social Activist in Science
by Jon Beckwith
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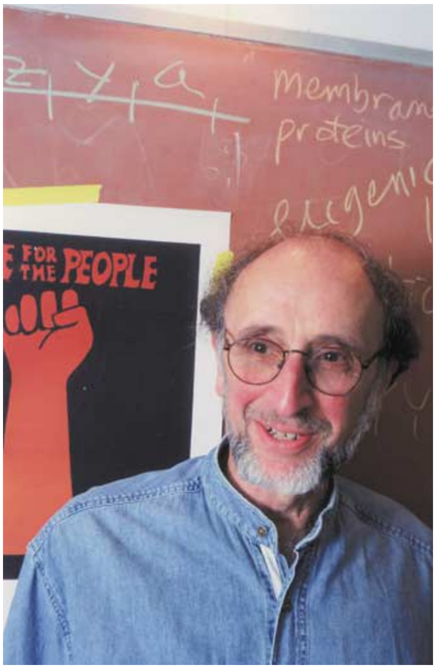
Ute Deichmann

"Science was puzzle-solving — figuring out mathematical proofs or devising pathways for the synthesis of complex organic compounds — it was fun." The joys of doing science, first experienced in college, motivated Jon Beckwith to become a scientist — and to remain one. He is now professor of microbiology and molecular genetics at Harvard Medical School. But literature, philosophy and social concerns have remained important to him throughout his scientific life. In 1969, Beckwith was the first to isolate a single gene from a chromosome (of the bacterium *Escherichia coli*) and, two decades later, his experiments on protein secretion from cells opened up new lines of research on the process of protein folding.

In this beautifully written autobiography, Beckwith explains these and his other scientific successes, as well as his failures. He vividly describes aspects of the "cultural revolution in science that molecular biology brought with it", epitomized by "iconoclastic and unchemist-like" Jim Watson, and major public controversies about genetics in the United States from the 1960s. Beckwith is acquainted with various laboratories in the United States and Europe, and characterizes the scientific styles of different individuals and groups. He was particularly fascinated with the French style of "daring leaps of logic", simple experiments that seemed to yield profound insights, and papers with persuasive "elegant rhetorical strokes", but later realized that it did not represent the process of how discoveries actually take place. He amply depicts the human elements, "the wrong turns, the surprises, the



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Social conscience: Jon Beckwith was the first to isolate a gene, but warned of the risks of genetics.

flashes of intuition, even the passions that drive us in science".

Beckwith's growing enchantment with science was mirrored by his growing concern for its consequences. His social activism in science grew out of a more general political radicalism in the 1950s and 1960s, stimulated especially by the civil-rights movement in the United States, the assassination of Martin Luther King, and the turmoil over the Vietnam War. As a member of the action group Science for the People, he was convinced that scientists have a special social responsibility, so he decided to help inform the public about the potential negative social consequences of genetic research. In 1969, in the same week that his famous paper about the first isolation of a gene appeared in *Nature* (**224,** 768–774), Beckwith called a press conference aimed at raising public awareness of the possible consequences of genetic manipulation.

This received huge international press coverage and contributed to rising fears, even among fellow scientists, about the possible dangers of molecular-biological research. But Beckwith fails to mention that most of the scientists who called for a moratorium on recombinant-DNA research in 1973, Watson and Paul Berg among them, later considered this a mistake and the fears unsubstantiated.

By contrast, Sydney Brenner, one of Beckwith's scientific heroes, never believed that scientists have a special social responsibility . In his autobiography, *A Life in Science* (BioMed Central, 2001), Brenner expressed the opinion that, in order to act responsibly, one should not prevent the generation of knowledge, but rather answer the following question: "What are you doing with your knowledge once you get it?" This, of course, presupposes the neutrality of science, which Beckwith denies.

Beckwith's activism was also an outcome of his preoccupation with history. He realized that, in contrast to physicists, who had openly confronted their historical burden of the past, the atomic bomb, geneticists were ignorant of their own 'atomic' history — their role in the eugenics movement. Suspicious of genetic research that claimed to explain antisocial behaviour, he launched a campaign against a study at Harvard Medical School on the development of boys with an extra Y chromosome (XYY). Beckwith was concerned about the ethics of identifying and studying these children, because many people still believed previous, seriously flawed scientific claims that linked this chromosomal aberration with criminal behaviour. The Harvard researchers finally decided to stop the screening. However, this campaign, because of the distrust it caused between the activists and faculty members, affected Beckwith's life more than any other.

E. O. Wilson's book *Sociobiology: The New Synthesis* (Harvard University Press, 1975) presented a new theory about genetic programmes of behaviour in animals and humans. It received wide media coverage. In their public attack on the theory, in which they said it was biologically determinist, Beckwith and his colleagues went as far as to associate Wilson and his theory with Nazism. Whether the scientific evidence that Wilson presented was strong or weak, some of the attacks were blatantly unfair. Social activists in science have to show responsibility, too.

In 1989 Beckwith joined the programme to explore and anticipate the ethical, legal and social implications of the Human Genome Project. The resulting public discussion of this issue led to the passage of bills outlawing the practice in several US states. At the time, the antagonism between genome scientists and activists seemed to be unbridgeable, which Beckwith interprets as part of the long history of conflict between the world of science and the humanities, as described by C. P. Snow in his *Two Cultures* (Cambridge University Press, 1959). Today, bioethicists and genome scientists seem to have begun to close this gap.

Beckwith's account of social activism in genetics implies that it arose from more than an analysis of the possible dangers. It could also be predicted from scientists' political inclinations: the same group of leftist scientists in the United States was critical of such different issues as recombinant DNA and genetic theories of human behaviour. That molecular biology attracted more critical and socially active scientists than did older sciences such as chemistry does not mean that molecular biology is intrinsically more